Climate change effects on Benguela sardine *Sardinops sagax*: From ecosystems to genes

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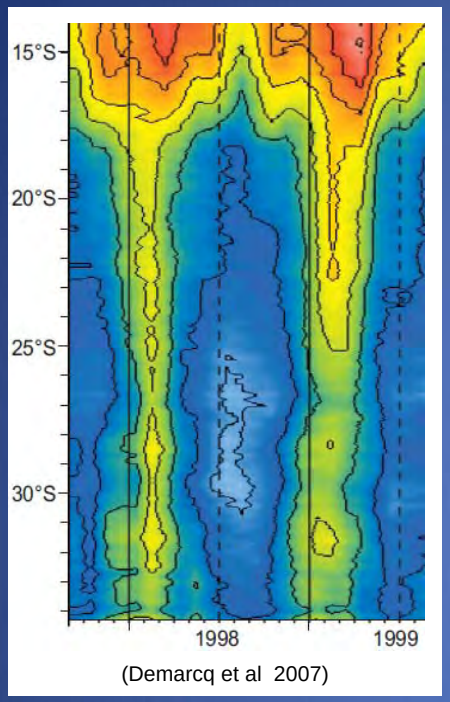
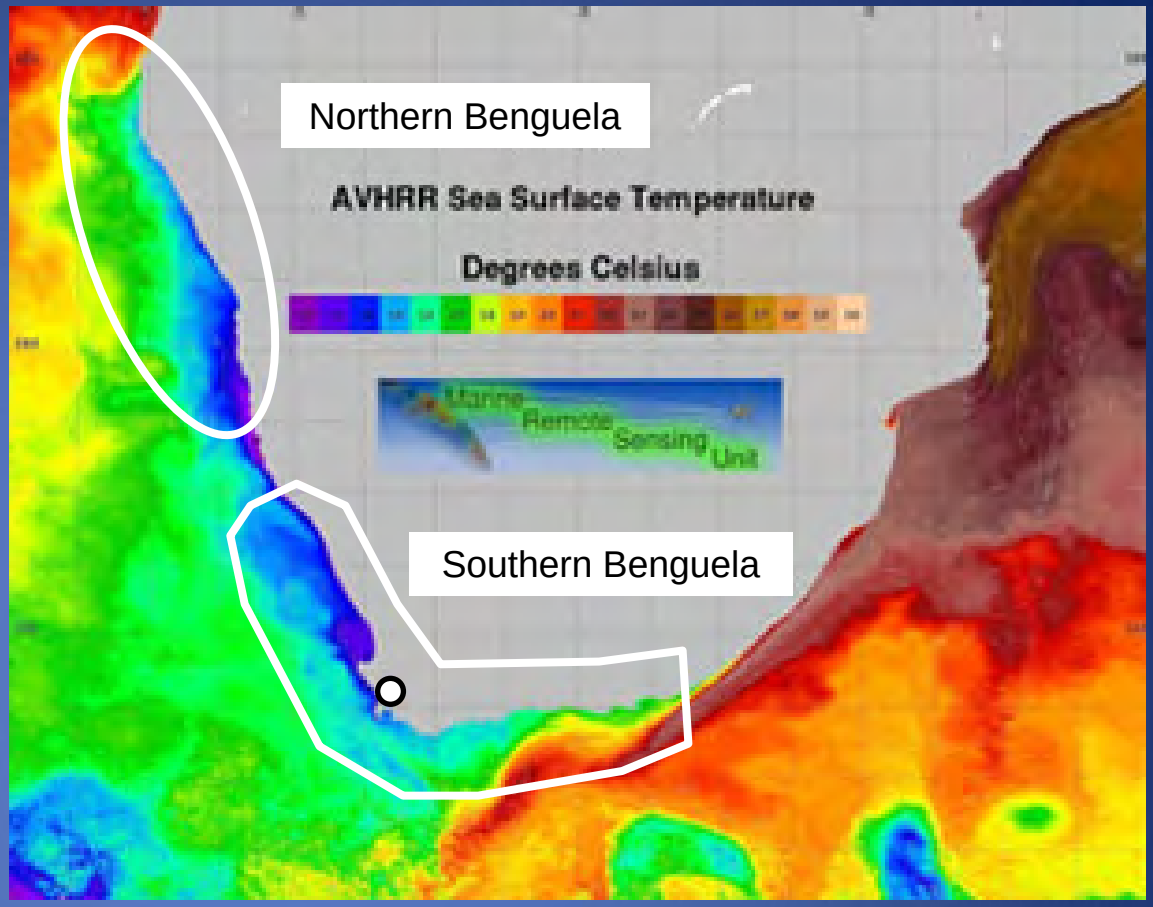
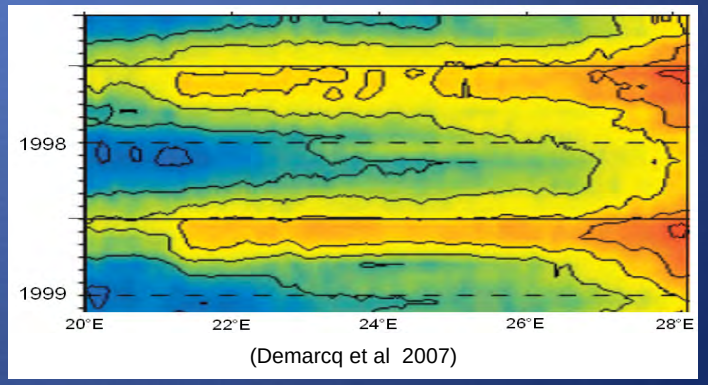
Introduction



(Demarcq et al 2007)



- Wind-driven coastal upwelling off west
- Warm temperate shelf off south
- Marked seasonality



(Demarcq et al 2007)

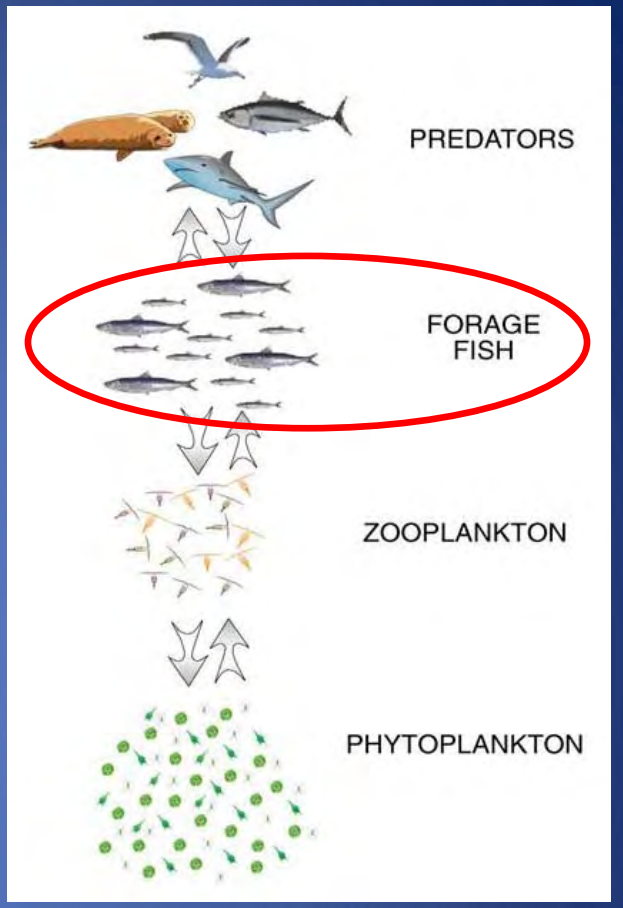
Introduction

- Small pelagic fish (sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus*) important for fisheries

- Human consumption, fish meal and oil

Introduction

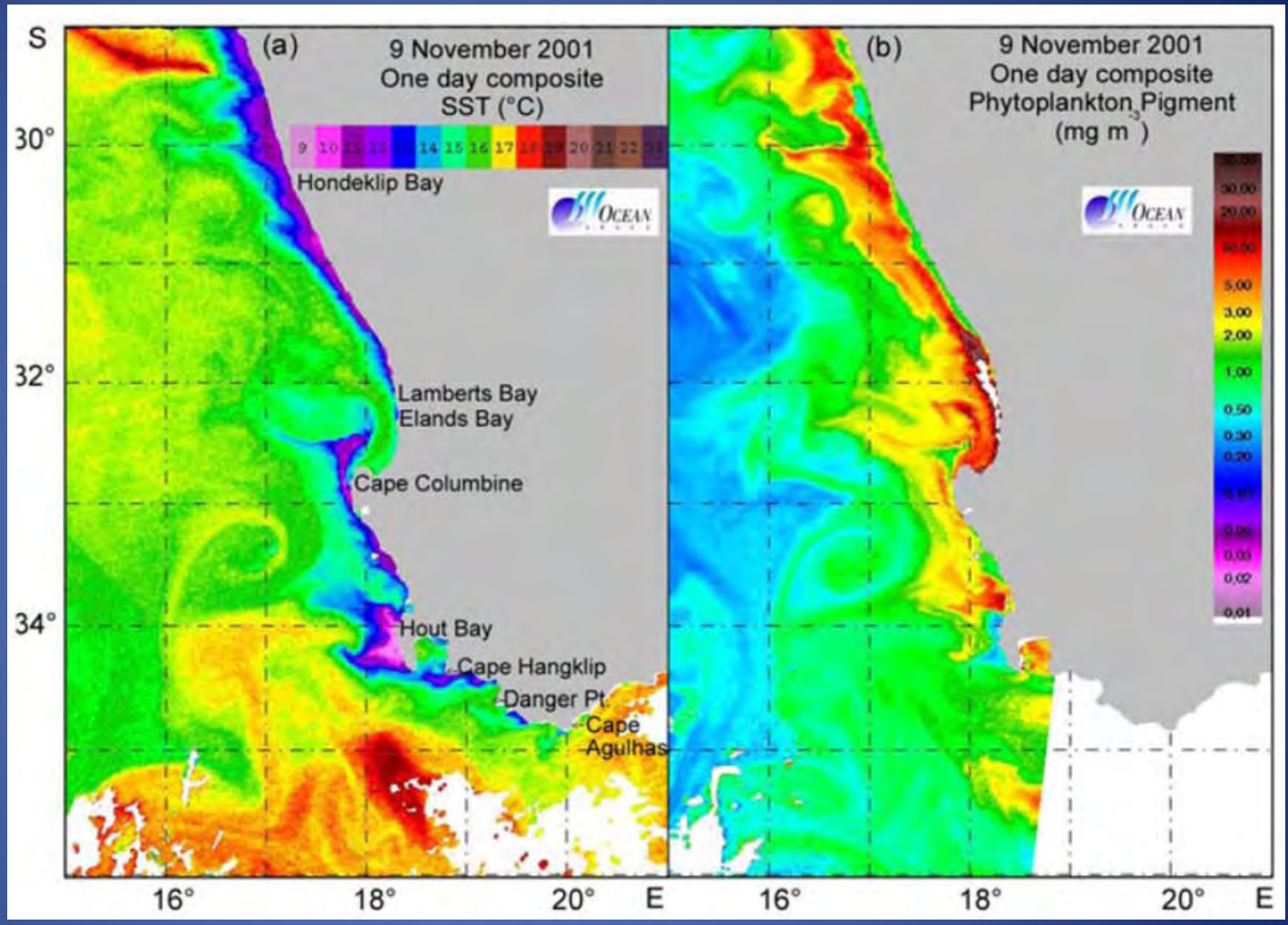
- Small pelagic fish also important to the ecosystem, being the forage of many predators



- Critical mid-trophic level regulates energy transfer

Variability

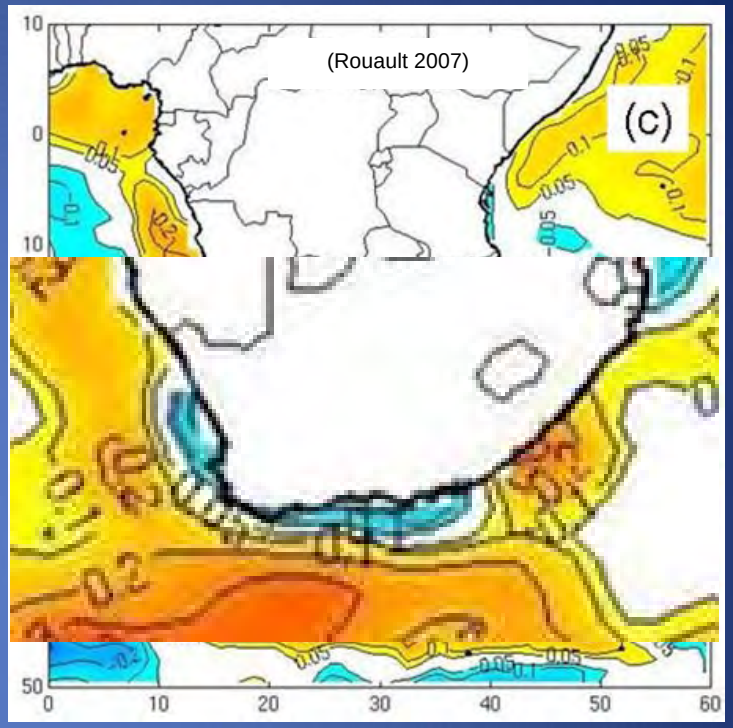
- Dynamic
- Mesoscale variability
- Low signal : noise ratio

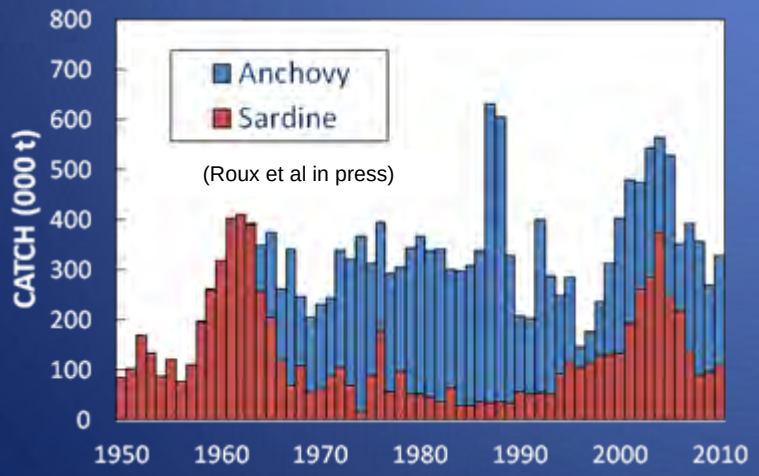


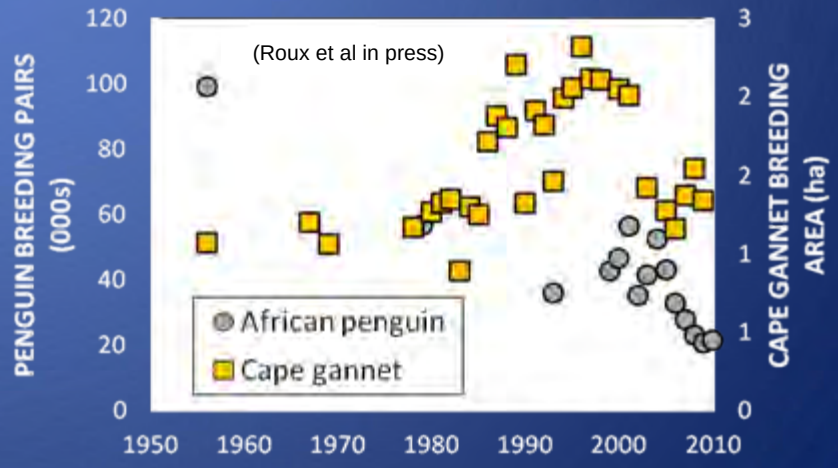
- Climate change impacts masked by environmental variability

Ecosystem: changes in the Southern Benguela

- Physical – decreasing SST (0.1-0.2°C per decade 1982-2005) inshore but increasing SST (0.2°C) off east coast and offshore
- Sardine – catches fluctuate and replacement by anchovy, small pelagics still abundant
- Predators – recent declines

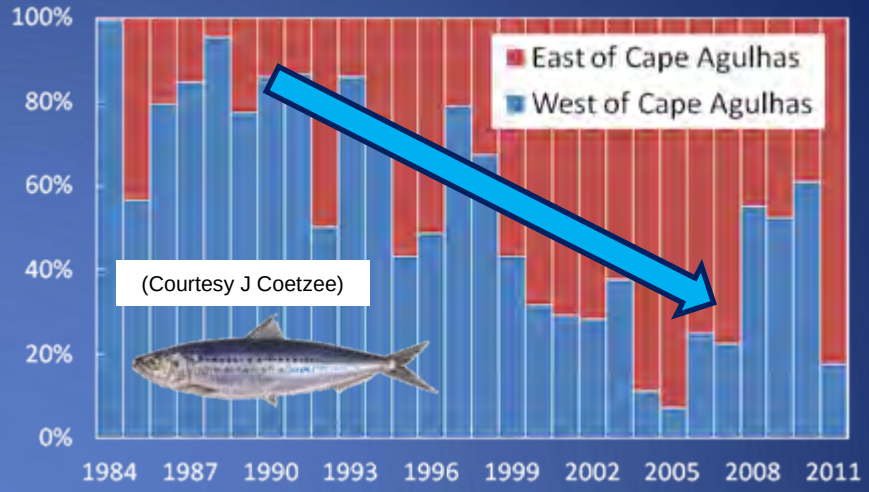


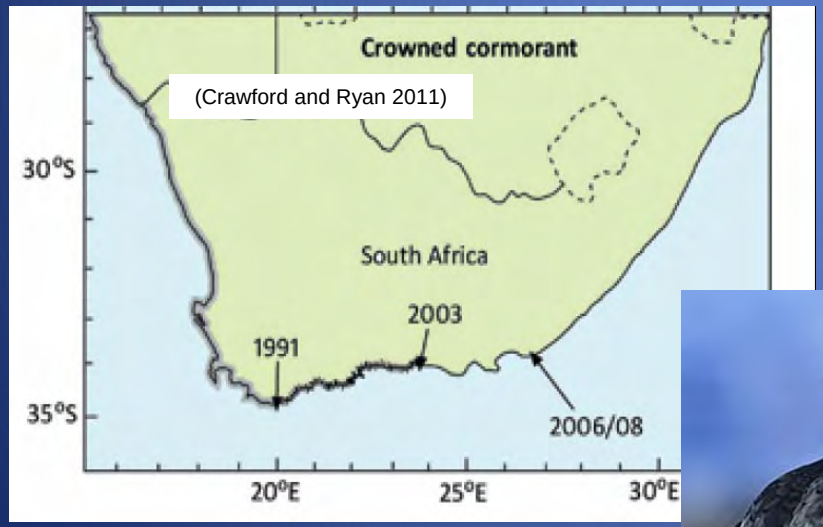


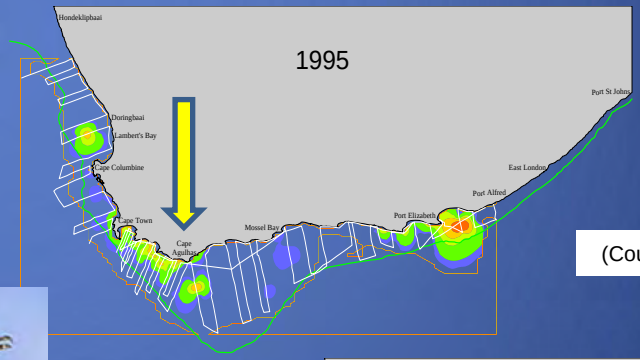


Ecosystem: changes in the Southern Benguela

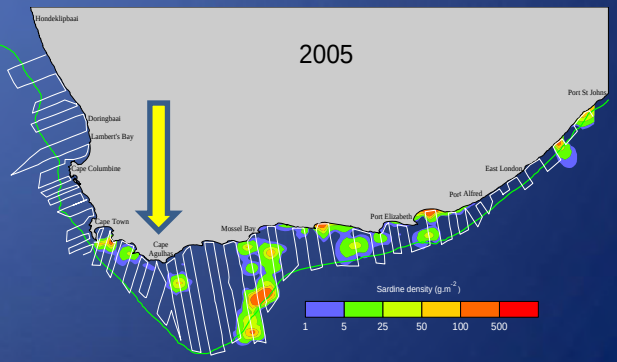
- Eastward shifts in distribution for sardine and anchovy
- Eastward shifts in distribution for other species (seabirds, rock lobster)





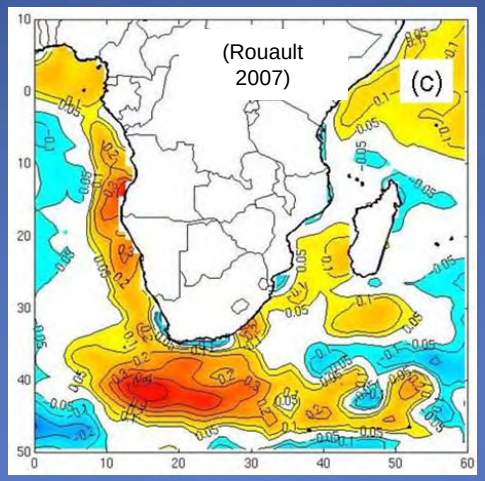


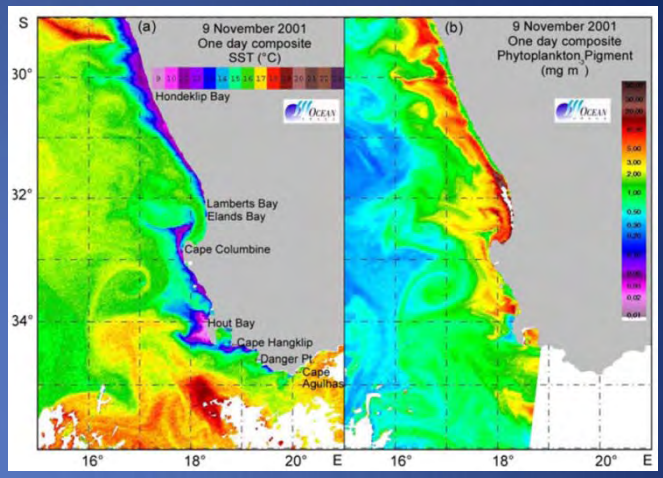
(Courtesy J Coetzee)



Environmental variability, climate change and fishing

- Observed distributional changes may be influenced by environmental variability or climate change

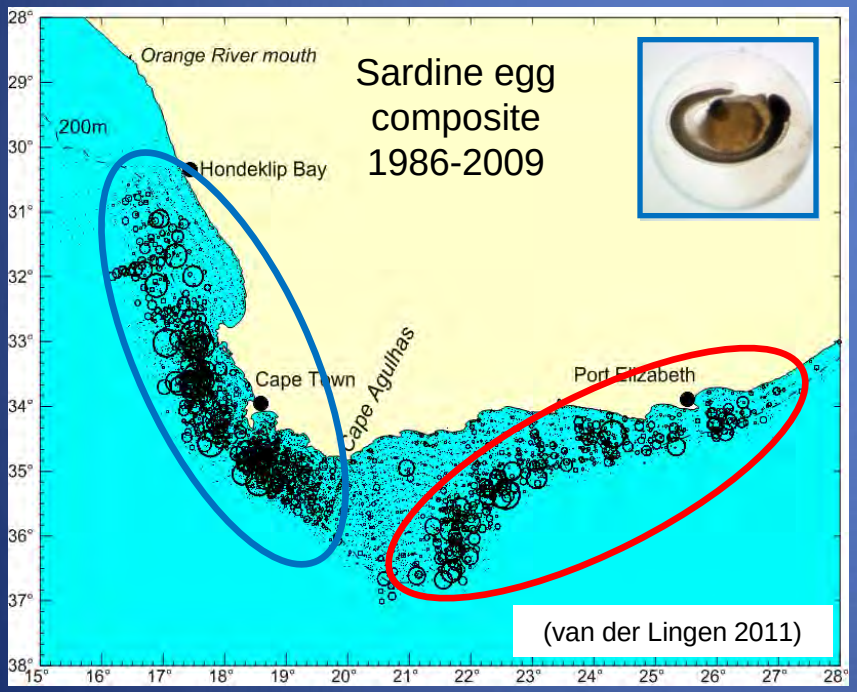




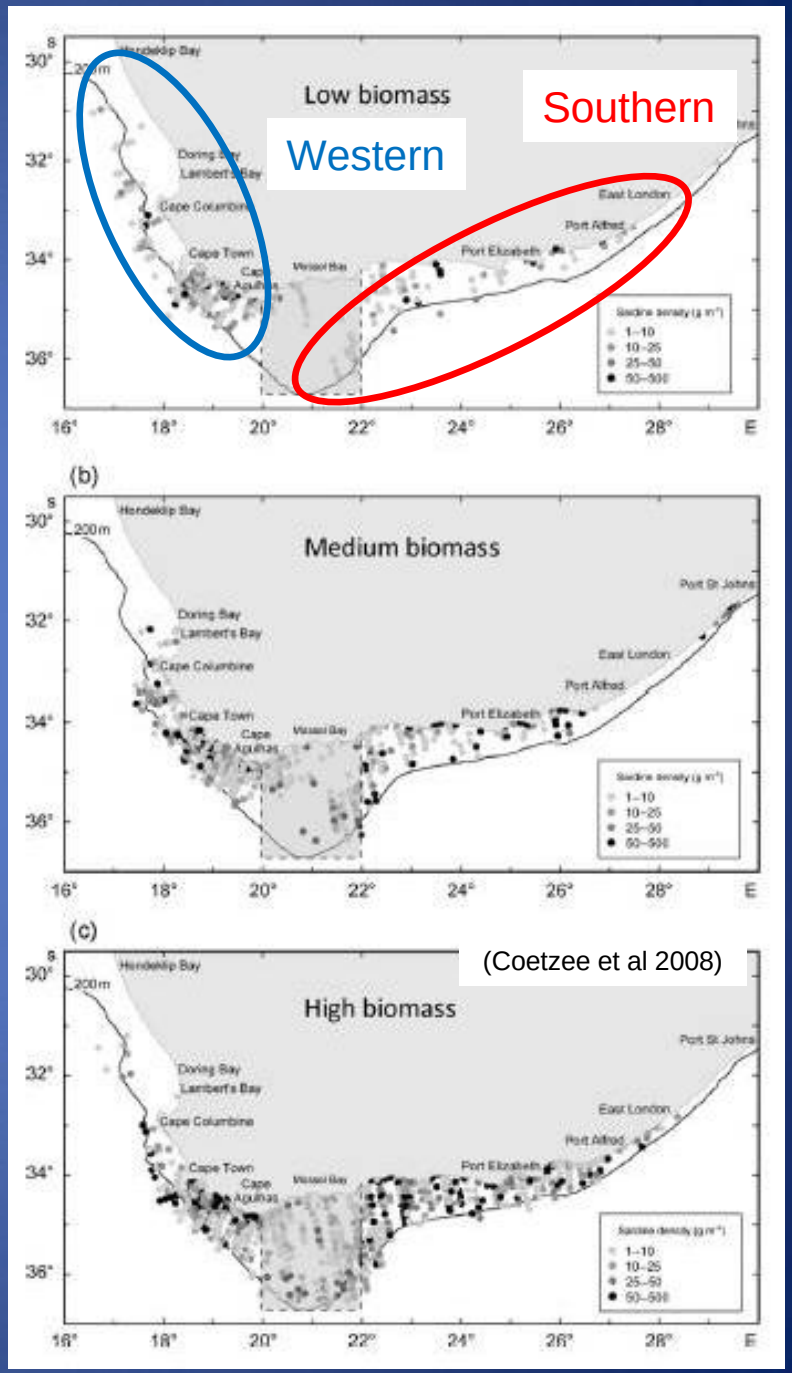
- But fishing is also important
- Interactions

Populations: multiple sardine stocks

- Recent analyses suggest the existence of putative “western” and “southern” stocks

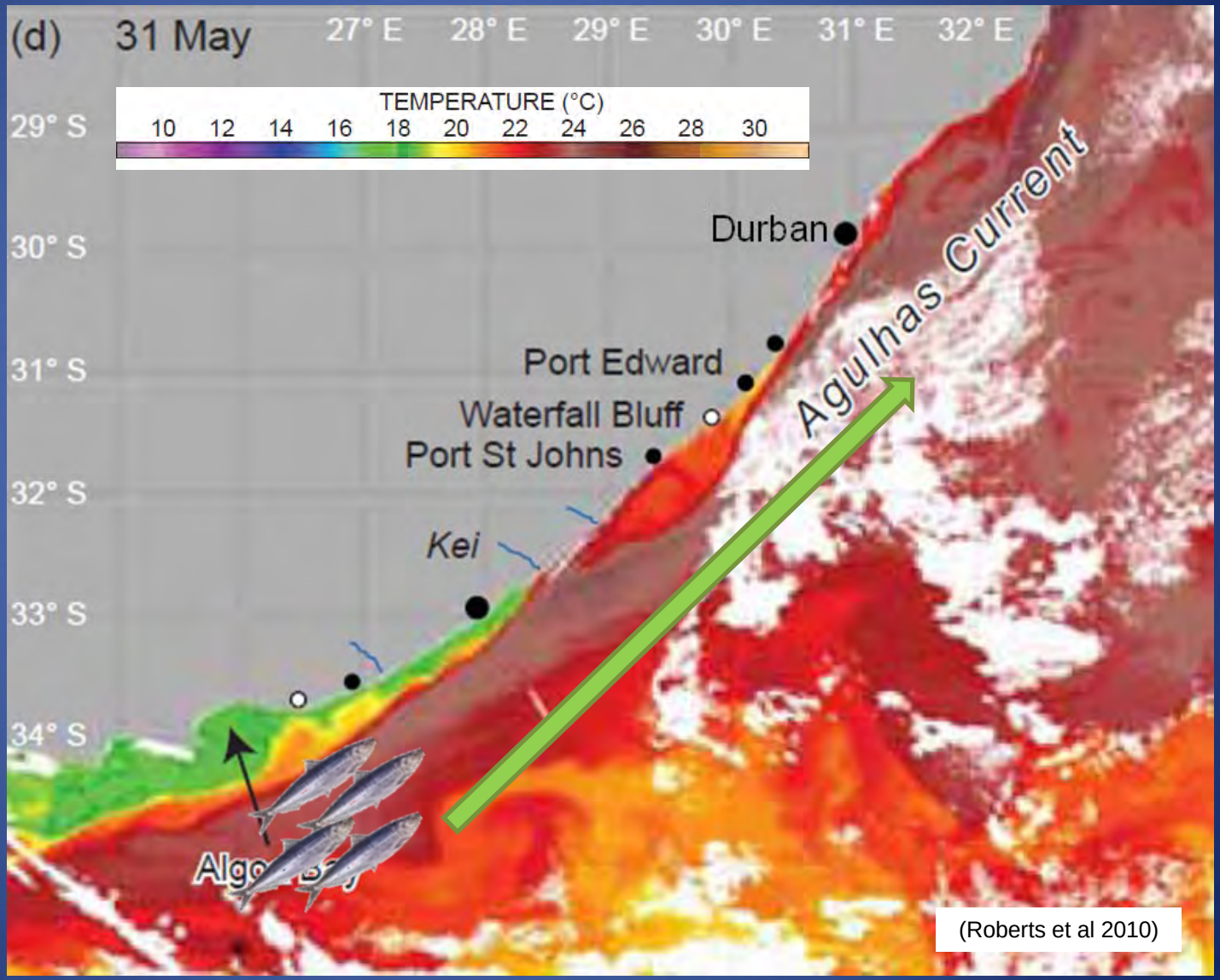


- Separate spawning grounds



Populations: multiple sardine stocks

- Putative "eastern" stock (winter sardine run)
- Against Agulhas Current
- Significant nutrient injection



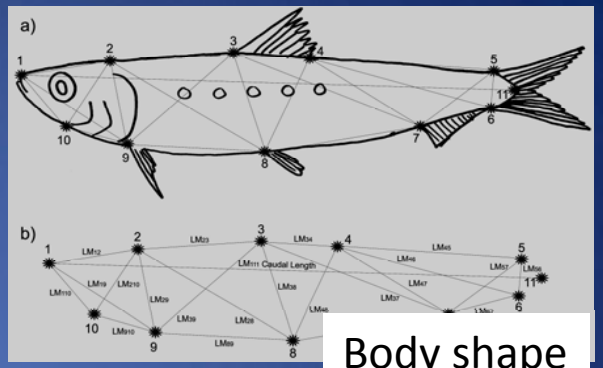
Populations: multiple sardine stocks

- Small beach-seine fishery, but substantially larger value for ecotourism

Photo: M. Addison

Individuals: multiple sardine stocks

- Multiple analyses support hypothesis of multiple sardine stocks off South Africa
  - Three stocks hypothesized
  - Different environments and different life histories

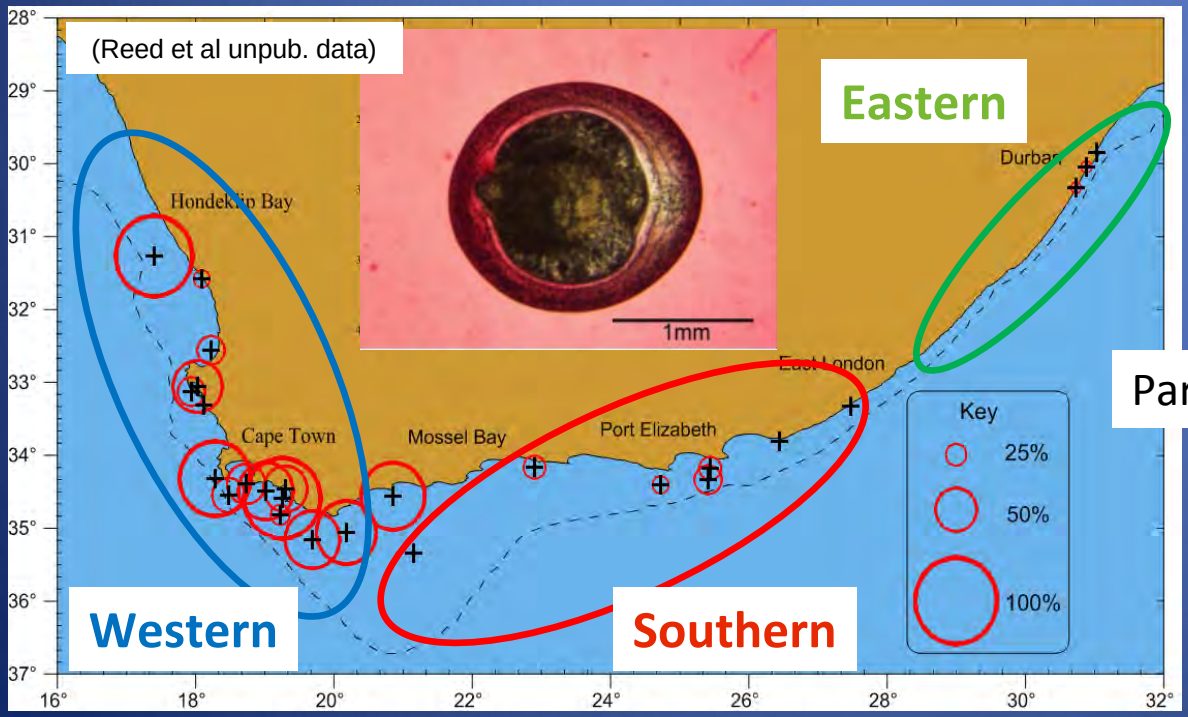


Body shape

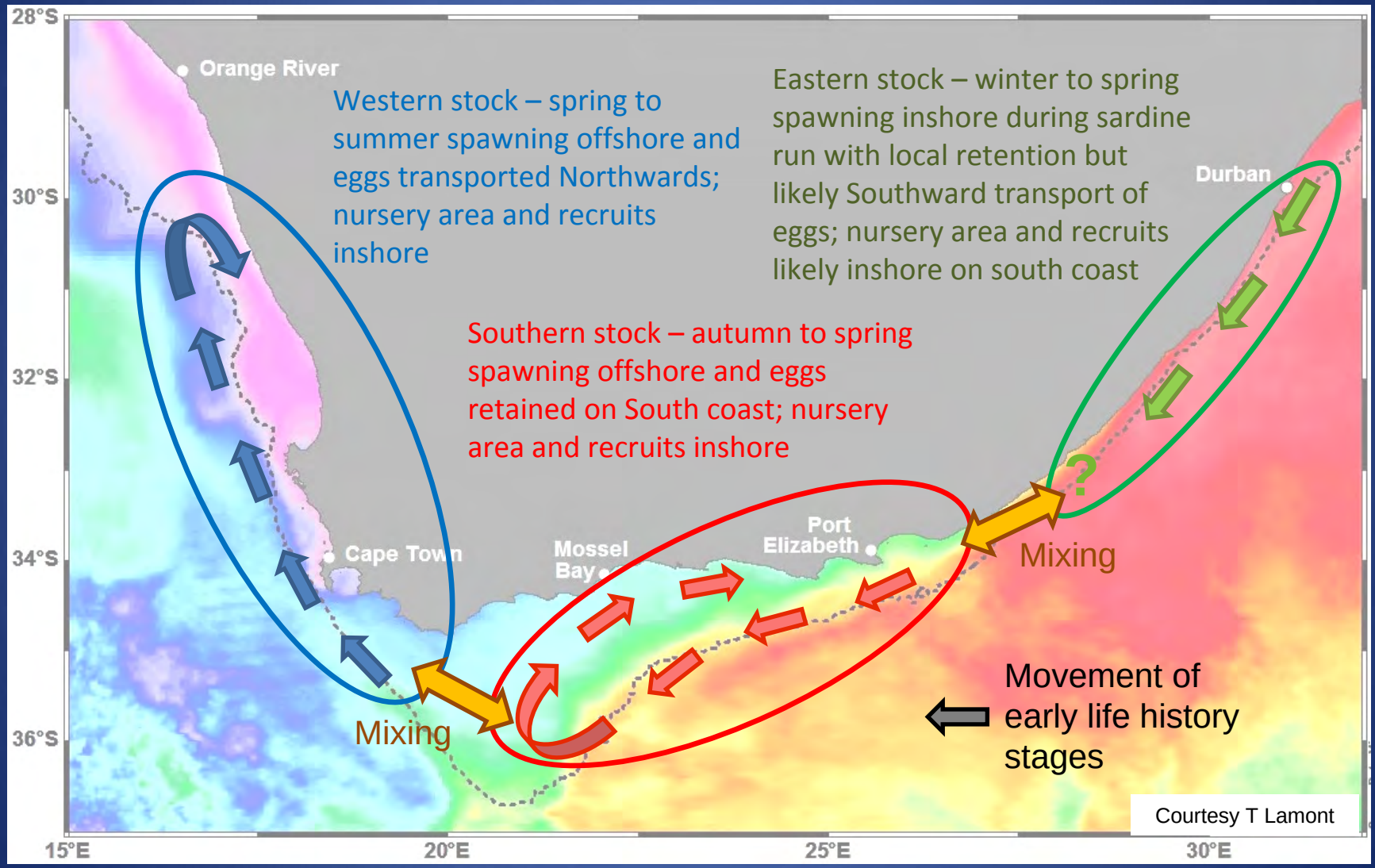
vertebrae

Gill rakers

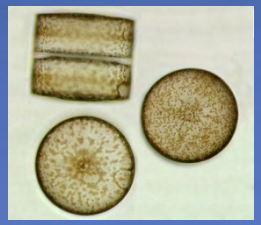
Parasites

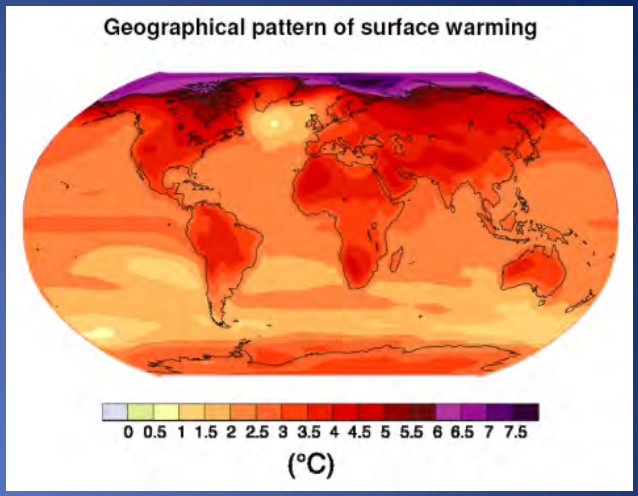


Stocks, individuals and life histories



Direct and indirect effects of climate change





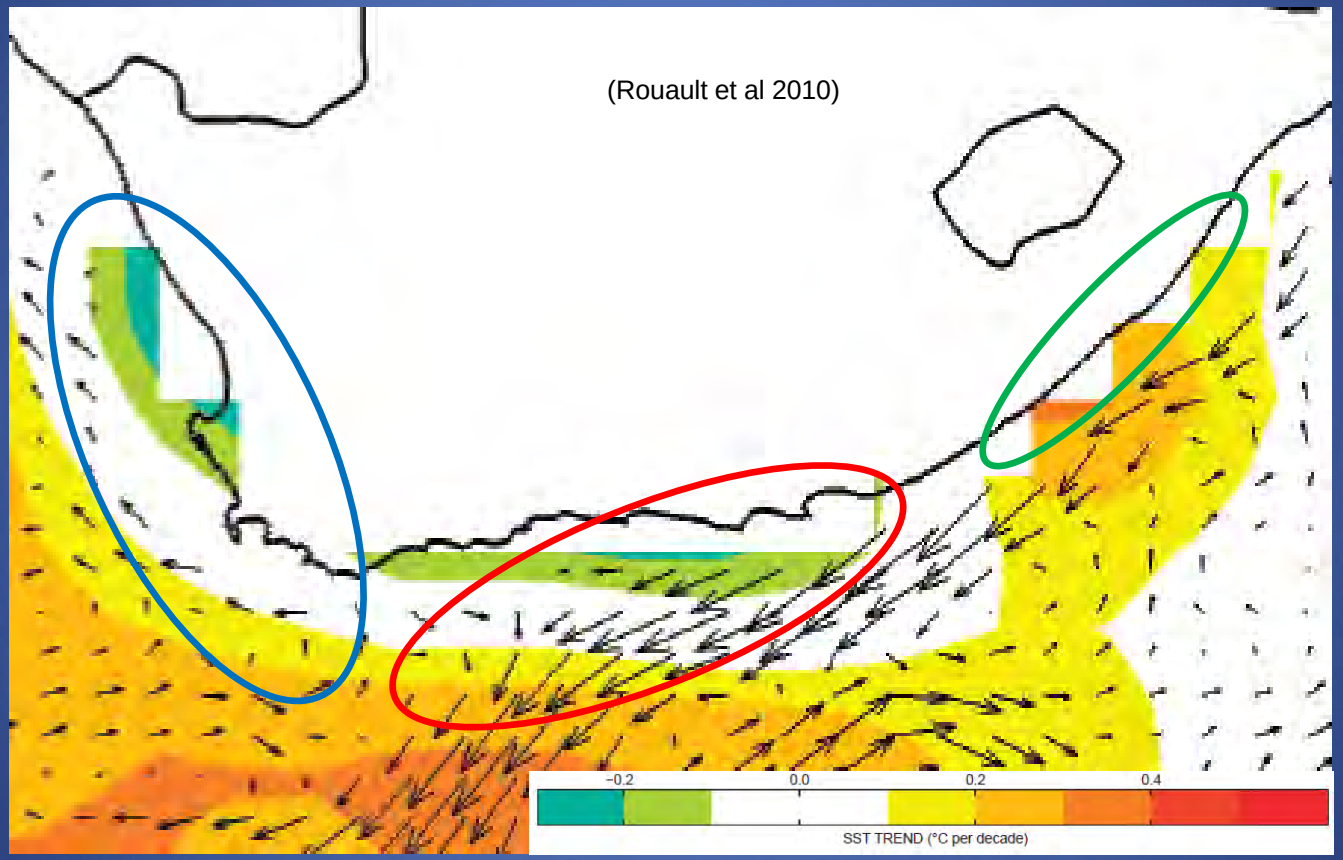
Temperature
Food

Sardine

Ecosystem

Temperature

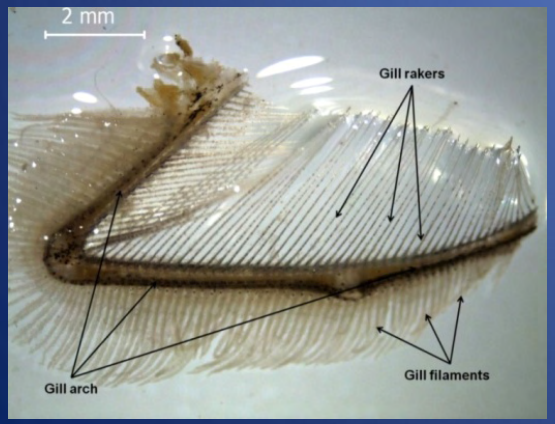
- Inshore cooling off west and south coasts may be beneficial (increased productivity) for western and southern stocks

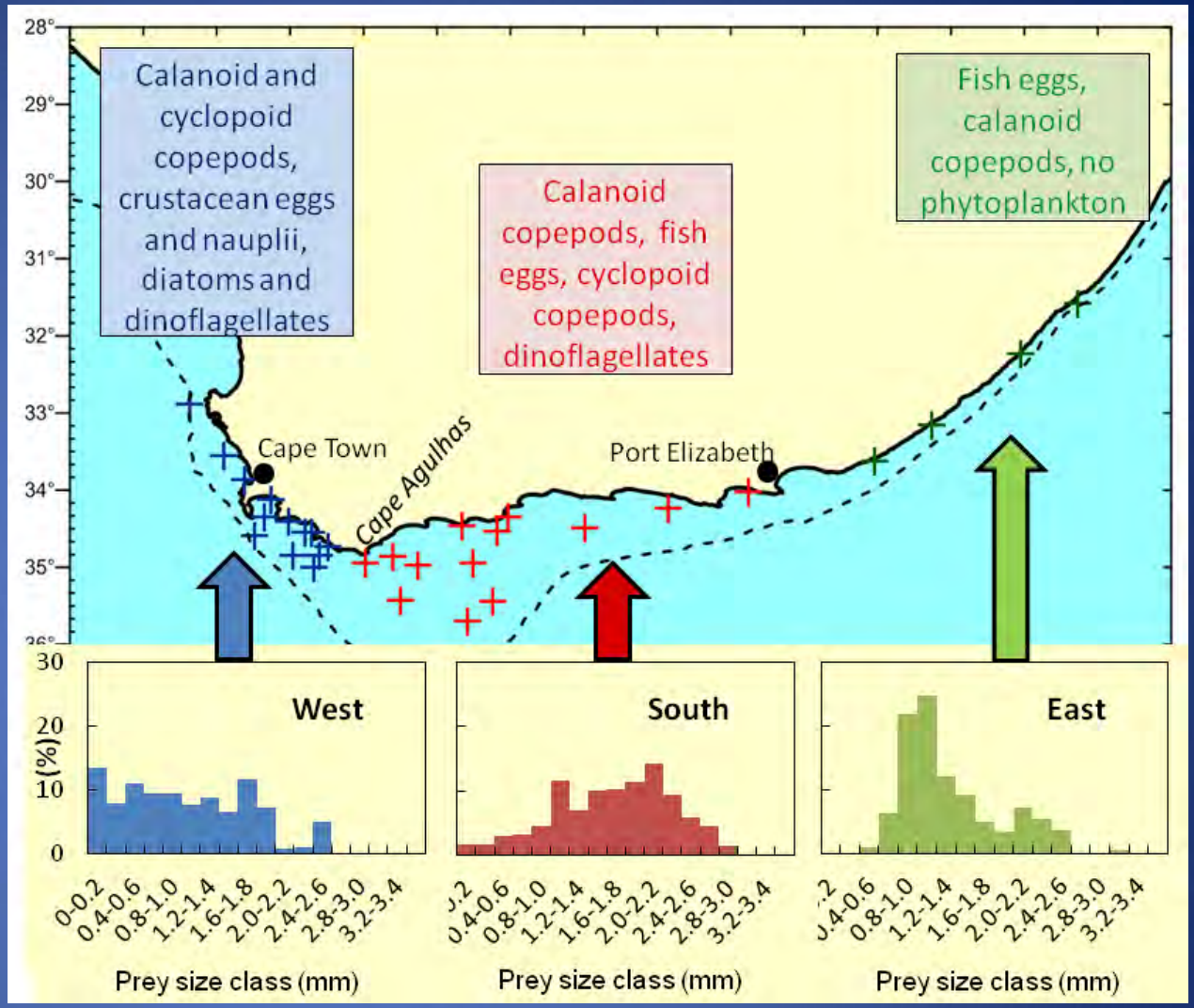


- Warming off east coast may be detrimental (impede the spawning migration) for eastern stock

Food

- Regional differences in sardine dietary composition and size
- Regional differences in gill raker gap





Small

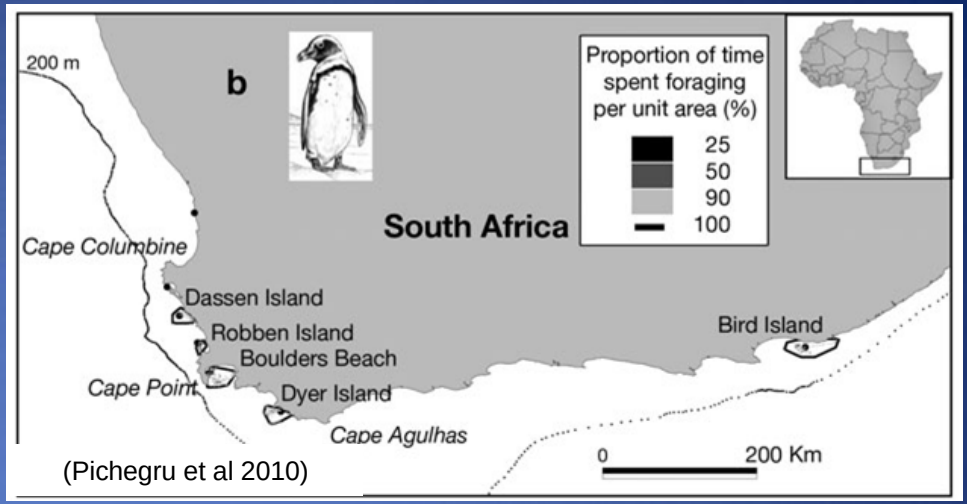
Medium

Large

Sardine and the ecosystem

- Reductions in local availability of sardine will have negative impacts on central-place foragers (i.e. penguins during their breeding season)

- Some predators (carcharhinid sharks) on the east coast have aligned their life histories with the sardine run

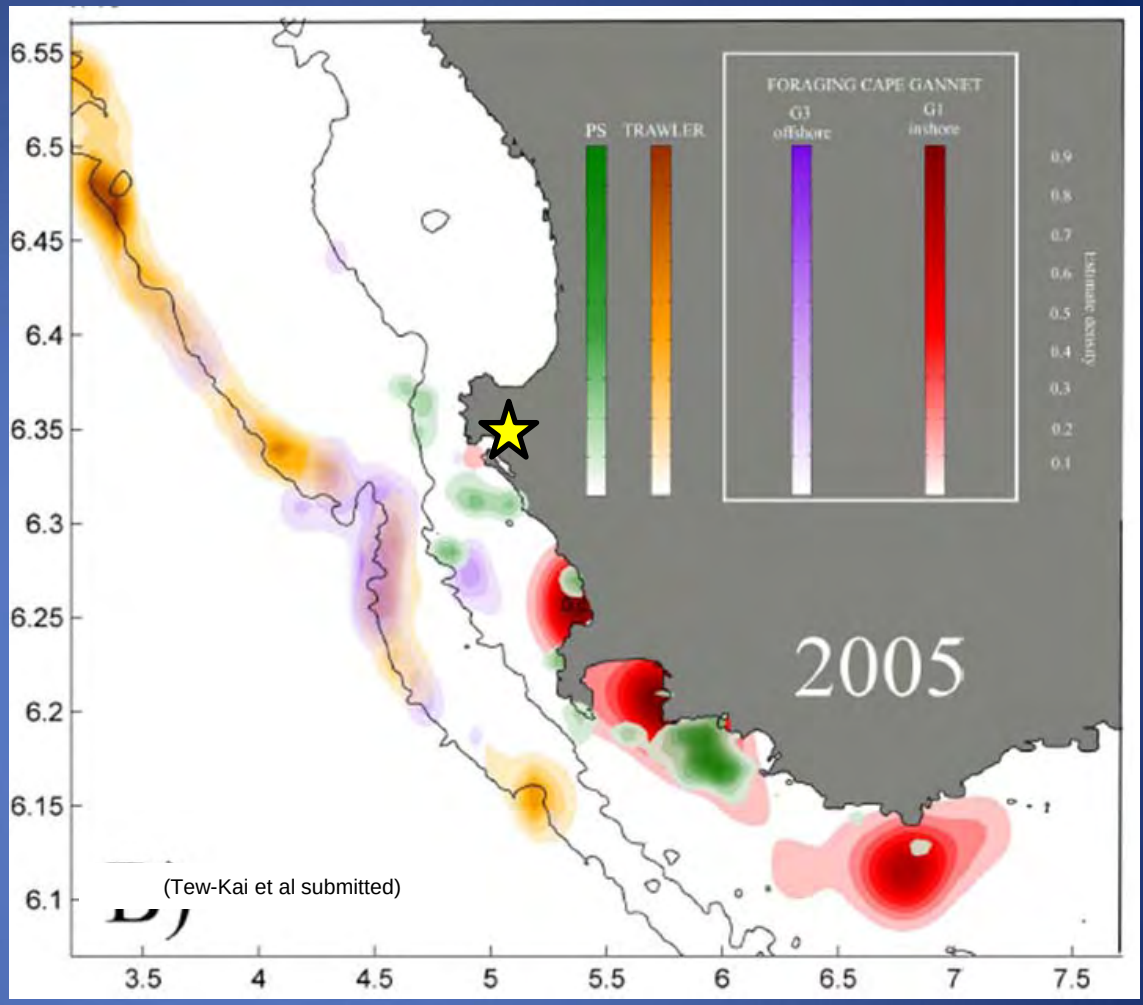


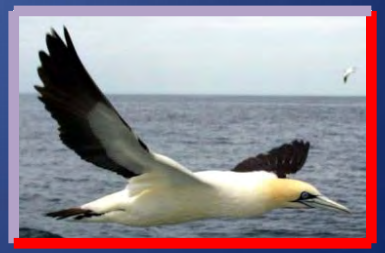
(Pichegru et al 2010)


Photo: R. Haestier

Sardine and the ecosystem

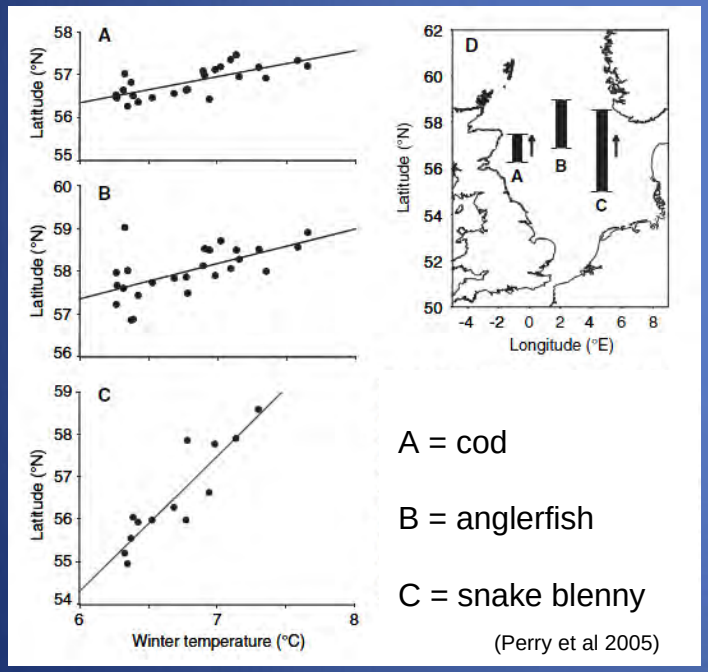
- Cape gannets foraged further offshore
- Switched to feeding on hake offal from demersal trawlers
- Lower food energetic content and increased foraging costs resulted in reduced breeding success





Responses to climate change: individuals

- Behaviour: poleward shifts in distribution observed for some Northern Hemisphere species

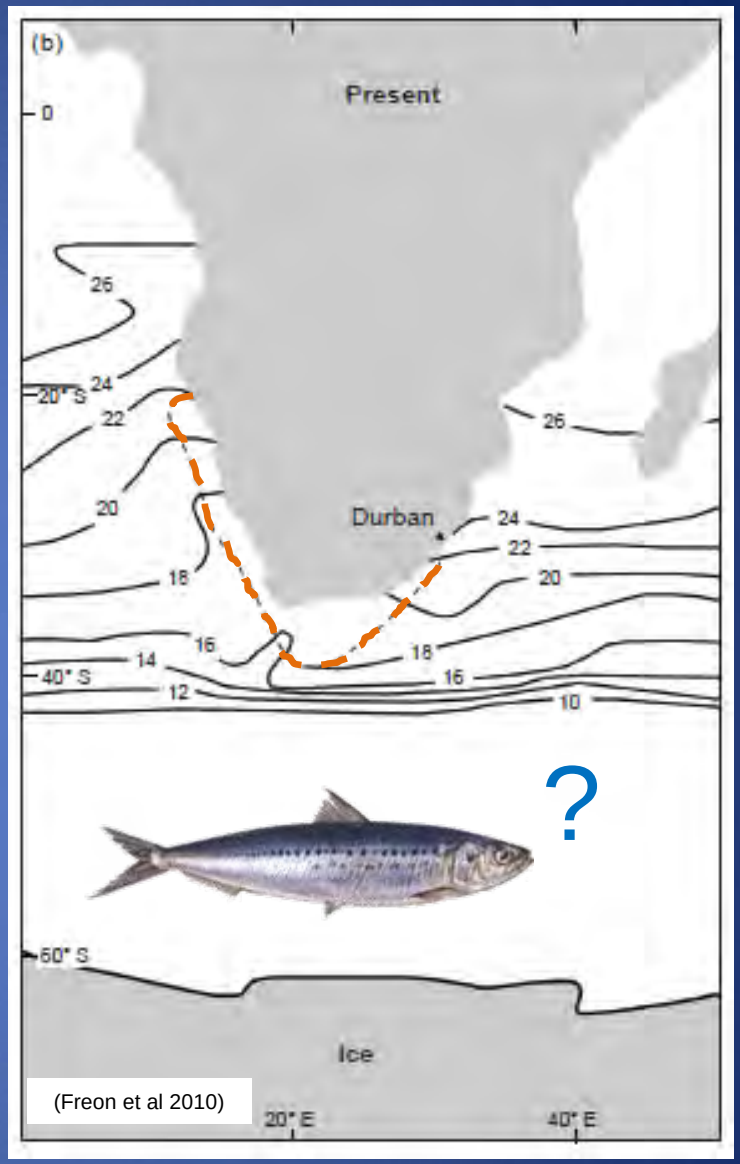


A = cod

B = anglerfish

C = snake blenny

(Perry et al 2005)

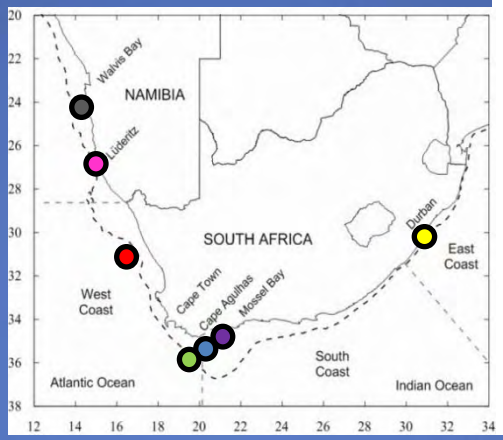


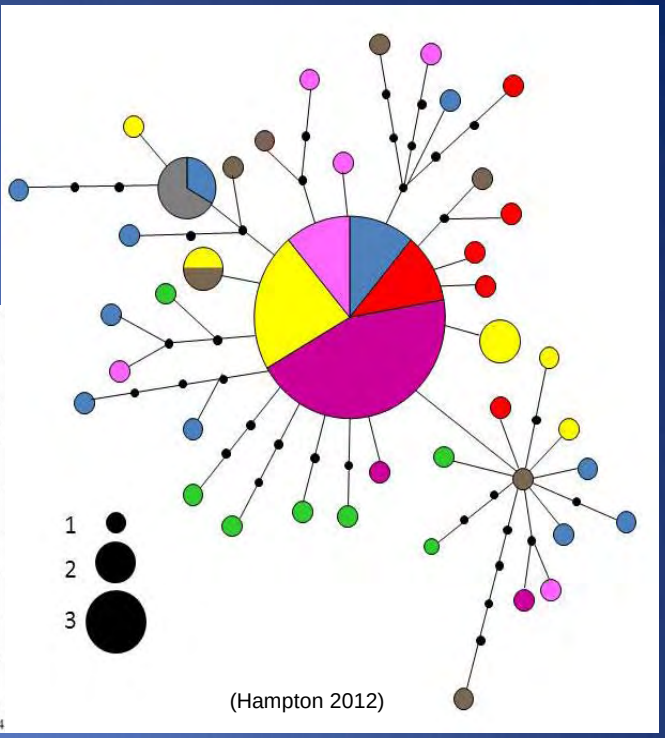
(Freon et al 2010)

- Nowhere (polewards) to go for sardine in the Benguela as they're at the southern end of the African continental margin

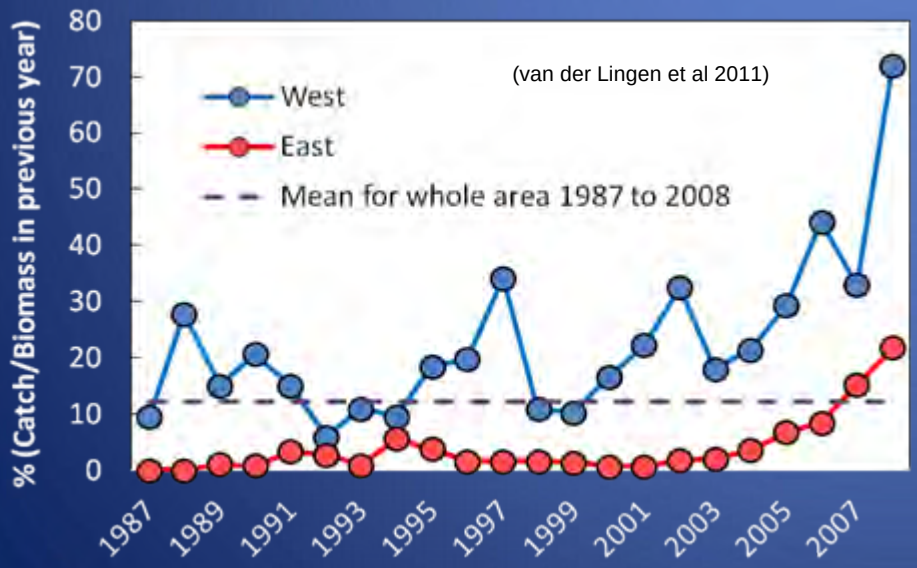
Responses to climate change: genes

- Adaptation (genotypic or phenotypic)
- Sardine mitochondrial DNA shows high haplotype diversity, but no spatial patterning





(Hampton 2012)

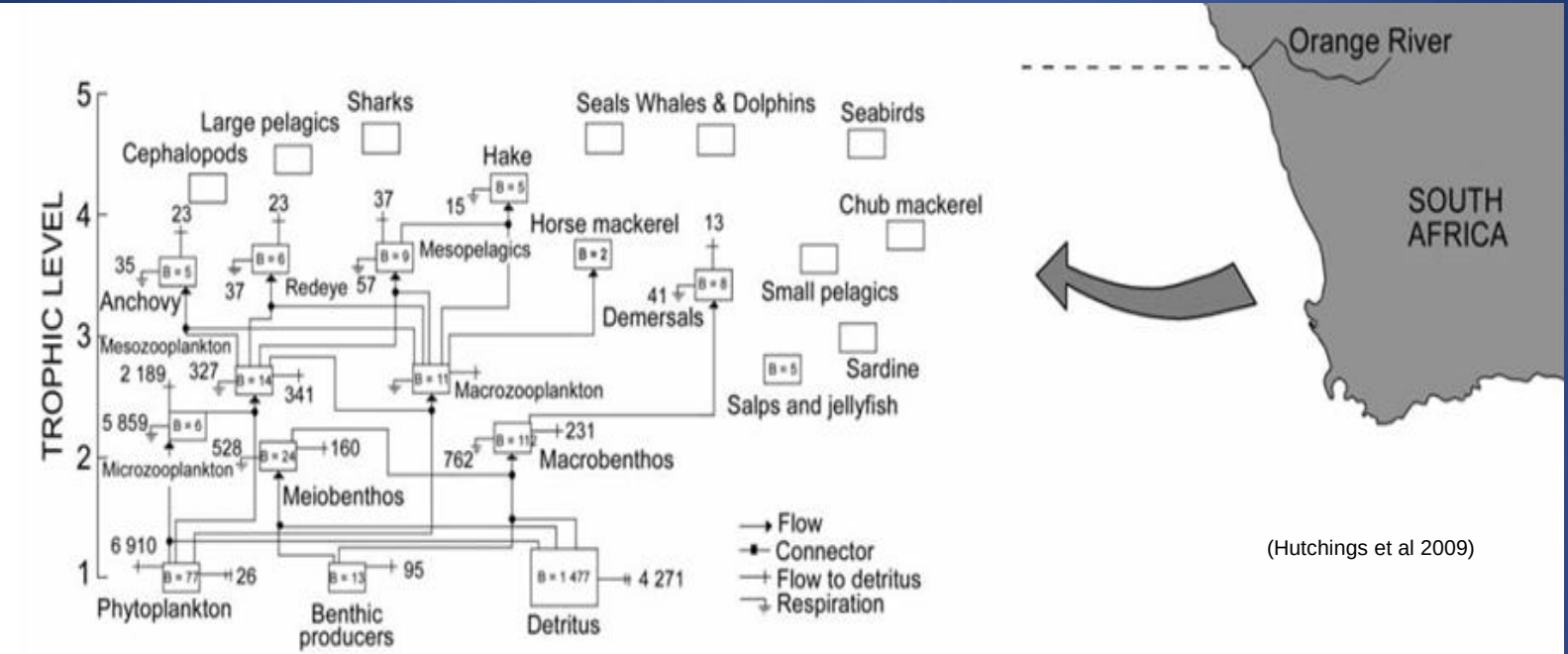


(van der Lingen et al 2011)

- Adaptability curtailed if genetic heterozygosity depleted by localized overfishing
- Fishing pressure higher on western stock

Complexity

- Ecosystems are complex (particularly their biology!)

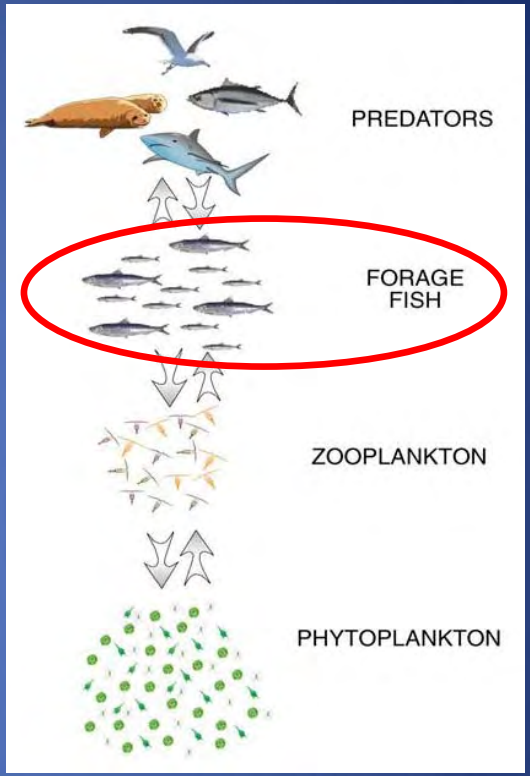


- Environmental variability and climate change will impact all levels within an ecosystem
- Difficult to predict ecosystem response (and responses of species, populations, stocks, individuals and their genes) without recognizing and accommodating complexity

Mitigating climate change effects in fisheries management

- Important to attempt to predict likely effects of climate change for key species

- Management needs to be adaptive and account for complexity where possible (eg. spatially explicit management)



Environmental variability and climate change

Ecosystem
Physical attributes
Species
Populations
Stocks
Individuals
Genes

Management

Acknowledgements and thanks

- Session 5 Conveners for invitation
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